

# **Operator Training: Booster Injection**

Created by P. Sampson

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*Modified by L. Hammons  
September 2007*

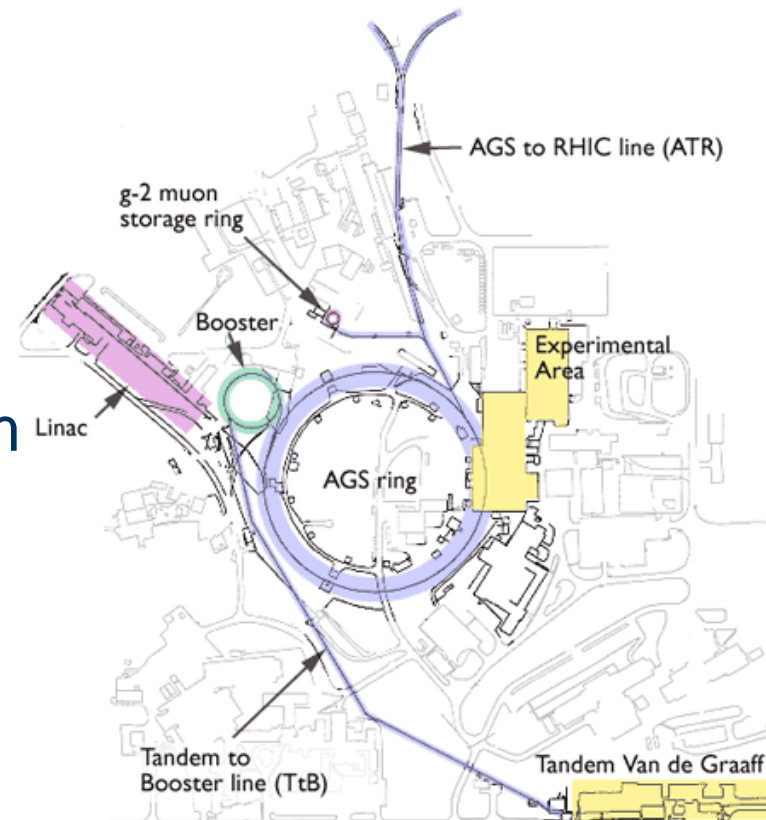


# Purpose

- The purpose of this training to introduce new operators to the basic features of Booster injection.
- A practical exam based on the information conveyed in this class will be given on a one-on-one basis in the upcoming weeks.

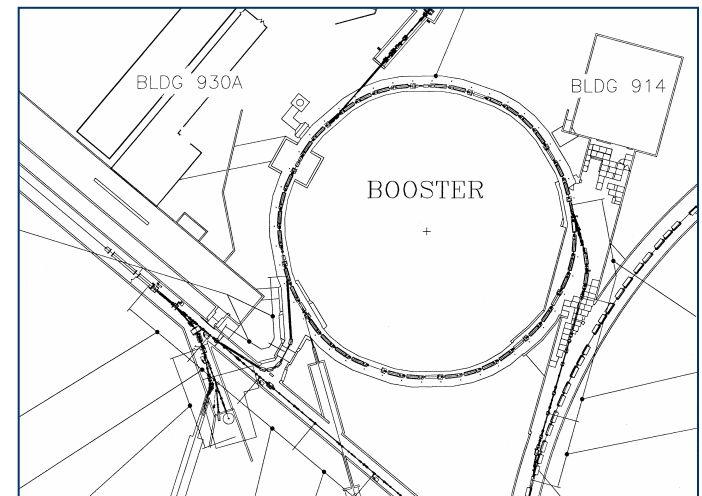
# Part One: Booster Injection

- Currently, all species of particles accelerated in the AGS must first be injected, accelerated, and extracted from the AGS Booster
- Two sources from which beam is delivered to the Booster
  - LINAC
  - Tandem Van de Graff



# The LINAC

- Two species of particles
  - High Intensity Proton Mode
  - Polarized Proton Mode
- Transported from source to the LINAC via LEBT
  - Low Energy Beam Transport
- LINAC accelerates protons to 200 MeV
- Transported to Booster via LTB transfer line
- Utilize stripping foil at Booster injection



# The Tandem van de Graff

- Pre-accelerates all species of ions to be injected into Booster
- Beam is transported to Booster via TTB transport line
- Stripping foil(s) in transport line are used to attain desired charge state for injection into the Booster
- An electrostatic inflector is used to inject beam into the Booster



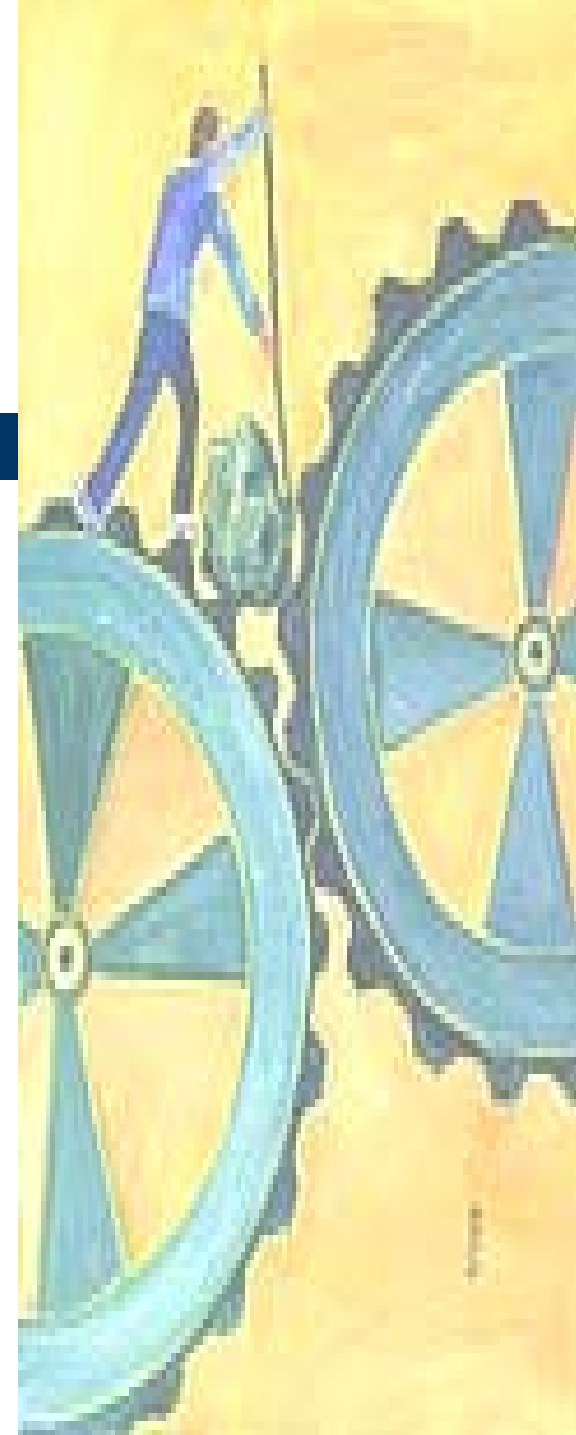


# Potential Problems

- Problems can be broken down into several categories:
  - Source parameters
  - Timing
  - Magnetics

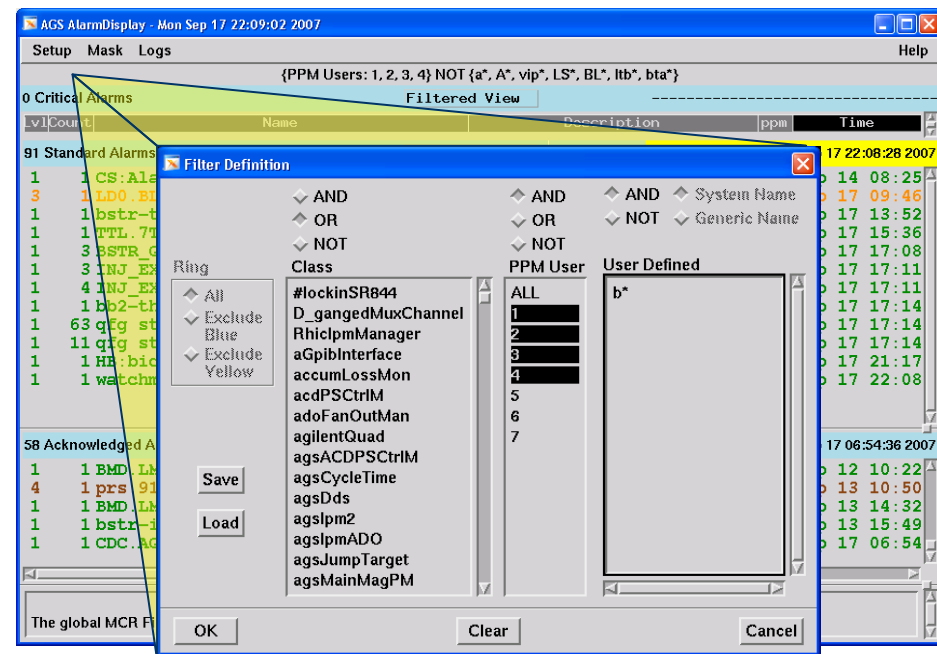
# Symptoms

- Causes of problems can be narrowed down by proper troubleshooting
  - Checking for symptoms
  - Assessing their significance



# Alarm Display

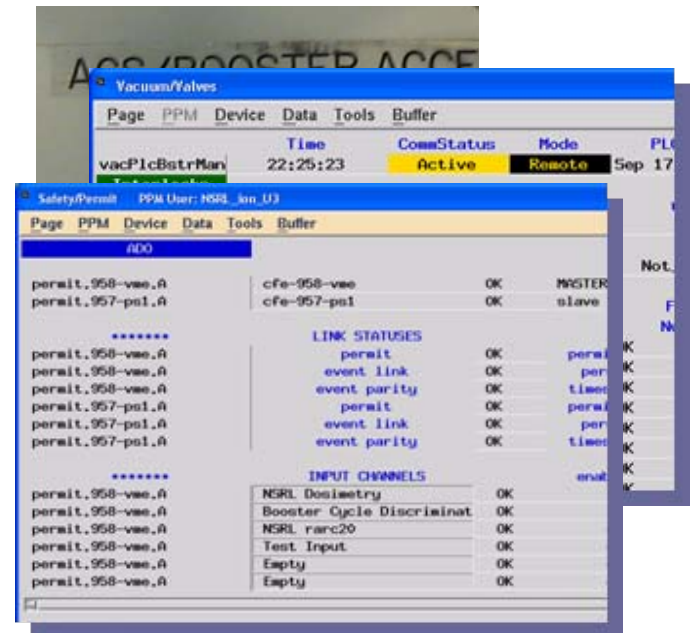
- Alarm Display (ADT) will likely show obvious problems
  - Many faults result in alarm on ADT
  - To simplify things, filter can temporarily be set to display only Booster alarms (set filter to b\*)





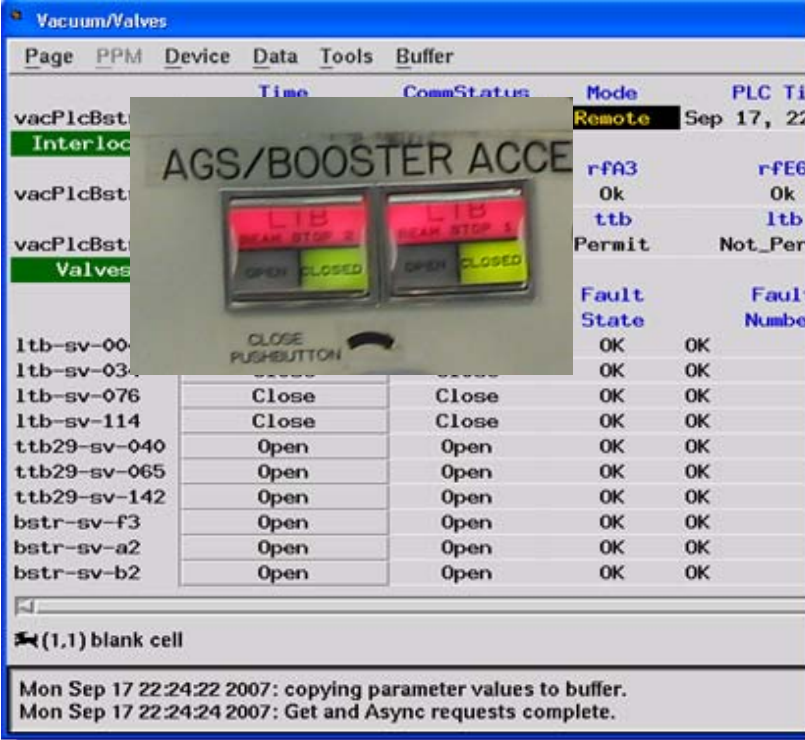
# LINAC Problems

- Chirping alarm during LINAC operation could indicate problem
- Check for obvious problems
  - Beam stops closed
  - Vacuum valves in
  - Permit link not valid
  - Booster beam inhibit latched
  - Device has tripped valves
  - LEBT timing is wrong



# LINAC Alarms

- If LTB beam stops are closed, check for interlocks or failures
  - Clear the problem and open the beam stops
- If vacuum valves in the Booster, LTB or BTA are closed, attempt to open them
  - If they open, problem is solved
  - If they do not open, check the vacuum gauges and check the vacuum.
  - Call the vacuum group for assistance.



The screenshot displays the 'Vacuum/Valves' control interface. It features a table with columns for Device, Data, Tools, Buffer, Time, CommStatus, Mode, and PLC Ti. The table lists various vacuum valves and their current states (Open/Closed) and fault status (OK/Not\_Permit).

Device	Data	Tools	Buffer	Time	CommStatus	Mode	PLC Ti
vacPlcBst	Interloc					Remote	Sep 17, 22
vacPlcBst	Valves					r-fA3	r-fE6
						Ok	Ok
						ttb	ltb
						Permit	Not_Per
						Fault State	Fault Number
ltb-sv-00						OK	OK
ltb-sv-03						OK	OK
ltb-sv-076	Close	Close				OK	OK
ltb-sv-114	Close	Close				OK	OK
ttb29-sv-040	Open	Open				OK	OK
ttb29-sv-065	Open	Open				OK	OK
ttb29-sv-142	Open	Open				OK	OK
bstr-sv-f3	Open	Open				OK	OK
bstr-sv-a2	Open	Open				OK	OK
bstr-sv-b2	Open	Open				OK	OK

Below the table, there is a physical control panel for the LTB beam stops. It features two red emergency stop buttons labeled 'LTB BEAM STOP 2' and 'LTB BEAM STOP 1'. Each button has 'OPEN' and 'CLOSED' indicators. Below the buttons is a 'CLOSE PUSHBUTTON'.

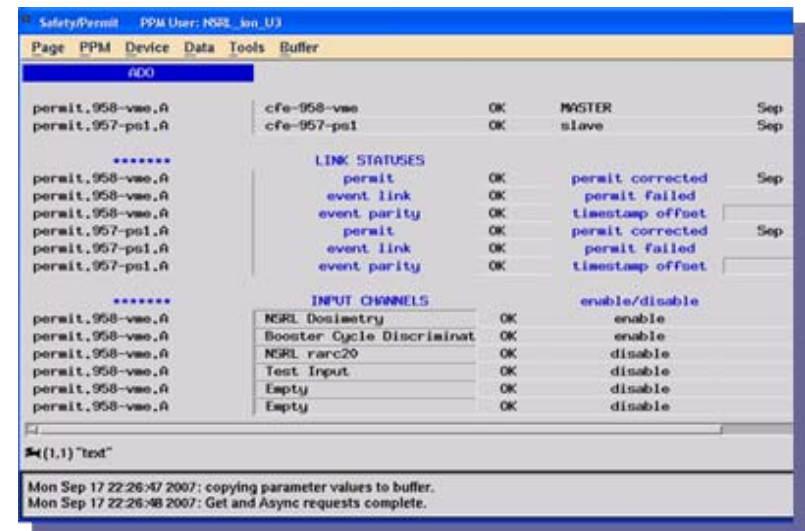
At the bottom of the interface, there is a status bar showing the following messages:

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(1,1) blank cell
Mon Sep 17 22:24:22 2007: copying parameter values to buffer.
Mon Sep 17 22:24:24 2007: Get and Async requests complete.
  
```

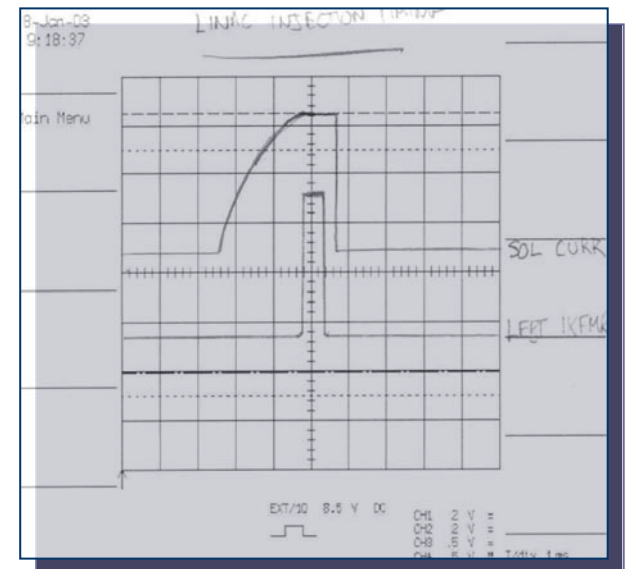
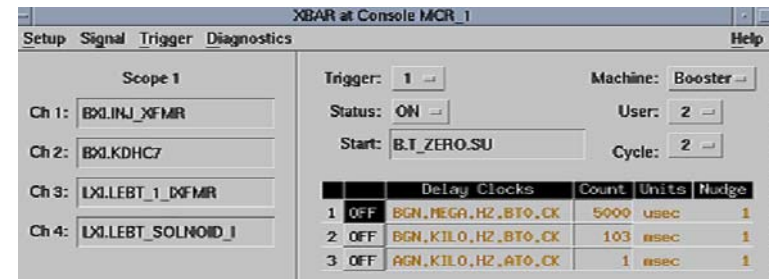
# LINAC Alarms

- If the permit link has failed, clear the offending input channel, reset link and continue
- If the Booster rad inhibit has latched, reset and continue
- If the inhibit latches more than once, correct the problem, reset and continue
- Device off:
  - Check ADT
  - Turn device on, continue



# LEBT Timing

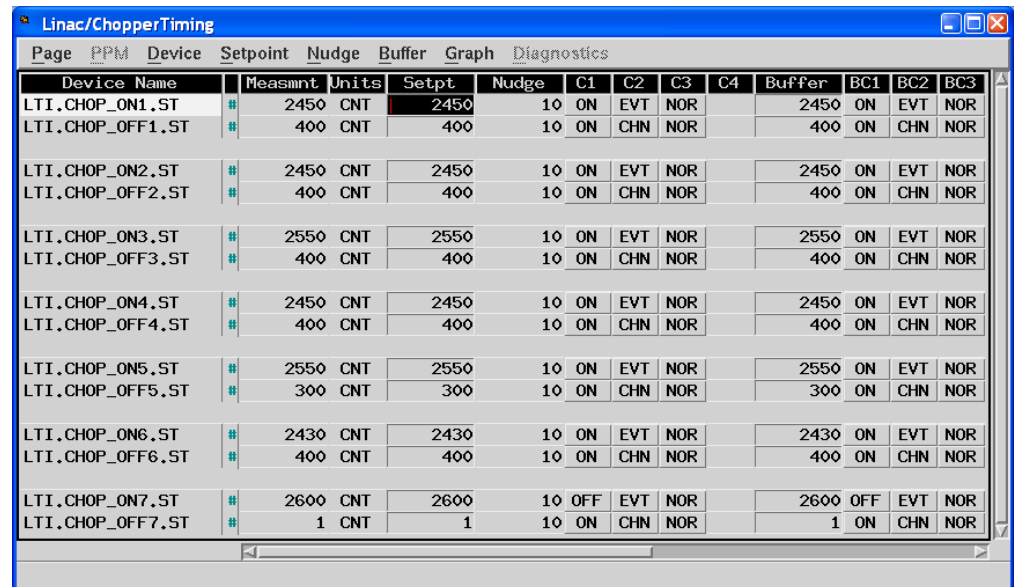
- Solenoids in the Low Energy Beam Transport (LEBT) are pulsed
  - Timing of pulse must coincide with the beam
  - Wrong timing will cause an audio chirp alarm
  - Connect the signals LEBT\_1\_IXFMR and LEBT\_SOLENOID\_I to a scope using XBAR
  - Flattop of quad pulse and beam current pulse should be aligned





# No LINAC Audible Alarm

- Check that the audio alarm is not acknowledged
- Check source output
  - Look at TV channel for LINAC source
- Check that the slow chopper is working and on



The screenshot shows a software window titled "Linac/ChopperTiming" with a menu bar (Page, PPM, Device, Setpoint, Nudge, Buffer, Graph, Diagnostics) and a table of device parameters. The table has columns for Device Name, Measmnt, Units, Setpt, Nudge, C1, C2, C3, C4, Buffer, BC1, BC2, and BC3. The data is organized into groups for LTI.CHOP\_ON1.ST through LTI.CHOP\_ON7.ST, each with a corresponding LTI.CHOP\_OFFX.ST row.

Device Name	Measmnt	Units	Setpt	Nudge	C1	C2	C3	C4	Buffer	BC1	BC2	BC3
LTI.CHOP_ON1.ST	#	2450 CNT	2450	10	ON	EVT	NOR		2450	ON	EVT	NOR
LTI.CHOP_OFF1.ST	#	400 CNT	400	10	ON	CHN	NOR		400	ON	CHN	NOR
LTI.CHOP_ON2.ST	#	2450 CNT	2450	10	ON	EVT	NOR		2450	ON	EVT	NOR
LTI.CHOP_OFF2.ST	#	400 CNT	400	10	ON	CHN	NOR		400	ON	CHN	NOR
LTI.CHOP_ON3.ST	#	2550 CNT	2550	10	ON	EVT	NOR		2550	ON	EVT	NOR
LTI.CHOP_OFF3.ST	#	400 CNT	400	10	ON	CHN	NOR		400	ON	CHN	NOR
LTI.CHOP_ON4.ST	#	2450 CNT	2450	10	ON	EVT	NOR		2450	ON	EVT	NOR
LTI.CHOP_OFF4.ST	#	400 CNT	400	10	ON	CHN	NOR		400	ON	CHN	NOR
LTI.CHOP_ON5.ST	#	2550 CNT	2550	10	ON	EVT	NOR		2550	ON	EVT	NOR
LTI.CHOP_OFF5.ST	#	300 CNT	300	10	ON	CHN	NOR		300	ON	CHN	NOR
LTI.CHOP_ON6.ST	#	2430 CNT	2430	10	ON	EVT	NOR		2430	ON	EVT	NOR
LTI.CHOP_OFF6.ST	#	400 CNT	400	10	ON	CHN	NOR		400	ON	CHN	NOR
LTI.CHOP_ON7.ST	#	2600 CNT	2600	10	OFF	EVT	NOR		2600	OFF	EVT	NOR
LTI.CHOP_OFF7.ST	#	1 CNT	1	10	ON	CHN	NOR		1	ON	CHN	NOR



# Ion Injection

- All species other than protons and polarized protons are pre-accelerated at the Tandem then transported to the Booster via TTB
- MCR Operations takes responsibility for the beam at section 27 of the TTB line
- Tandem Operations is responsible for areas upstream of 27

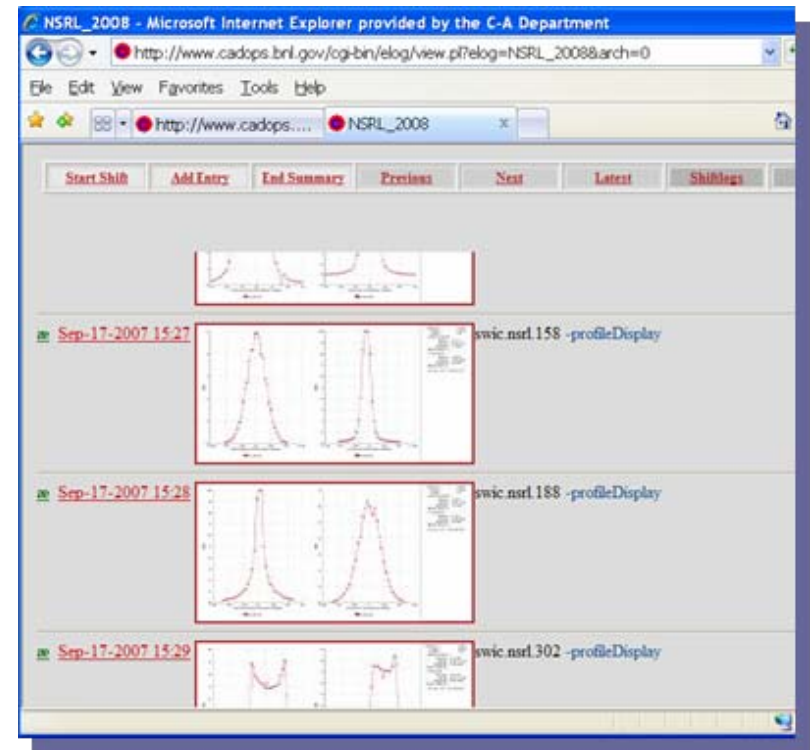
# Tandem-to-Booster

- TTB magnets are controlled via pet
- Readbacks for power supplies in TTB must be within tight tolerances or they will generate an alarm
- A potential problem arises when the 'SCAN' control is off for a particular section of TTB
  - When scan is off, there is no communication between controls and power supplies.
  - If a supply was adjusted with scan off, it may generate a false alarm.

BoosterInjection/Tbl/C_section 29 PPM User: Gold_ut												
Page	Device	Setpoint	Nudge	Buffer	Graph	Diagnostics						
Device Name	Measmnt	Units	Setpt	Nudge	C1	C2	C3	C4	Buffer	BC1	BC2	BC3
TTL_28TDV2	#	0.00397	A	0.00092	0.02000	ON			0.00092	ON		
TTL_28TDH2	#	0.20081	A	0.19746	0.00500				0.19746			
BTI_28MW132	#				OUT	NOR	REM			OUT	NOR	
BTI_28FC132	#				OUT	NOR	REM			OUT	NOR	
TTL_290V1	#	3.20231	A	3.23893	0.03000	ON			3.23893	ON		
TTL_290H1	#	2.76816	A	2.77350	0.03000	ON			2.77350	ON		
TTL_29TDV1	#	0.12299	A	0.12024	0.02000	ON			0.12024	ON		
TTL_29TDH1	#	-0.19318	A	-0.20234	0.02000	ON			-0.20234	ON		
BTI_29MW090	#				OUT	NOR	REM			OUT	NOR	
TTL_290H2	#	8.21598	A	8.03744	0.02000	ON			8.23735	ON		
TTL_290V2	#	8.31823	A	8.34188	0.02000	ON			8.34188	ON		
TTL_29DV1	#	3.99812	A	4.01887	0.00500	ON			4.01887	ON		
TTL_29TDH2	#	-0.02289	A	-0.03006	0.01000	ON			-0.03006	ON		
TTL_29TDV3	#	-0.46327	A	-0.47136	0.02500	ON			-0.47136	ON		
TTL_29TDH3	#	2.09327	A	2.10975	0.01000	ON			2.10975	ON		
BTI_29MW141	#				OUT	NOR	REM			OUT	NOR	
BTI_29FC141	#				OUT	NOR	REM	OFF		OUT	NOR	
TTL_SCAN3_CTL	#				OFF	DP1	NH1	NH2		ON		
BIJ_SPTMC3_STAT	#				ON					ON		
BIJ_SPTMC3_SPRB	#	52.653	KV	24.999	0.020	NOR			24.999	NOR		

# Troubleshooting TTB Injection

- No Beam:
  - Check the obvious.
    - Are there reasonable Booster Input numbers?
  - Get records of good running conditions
    - E-logs
    - End-of-day documentation
  - Look for beam in TTB
    - Current transformers
    - Harps
    - Cups



# No Ion Beam

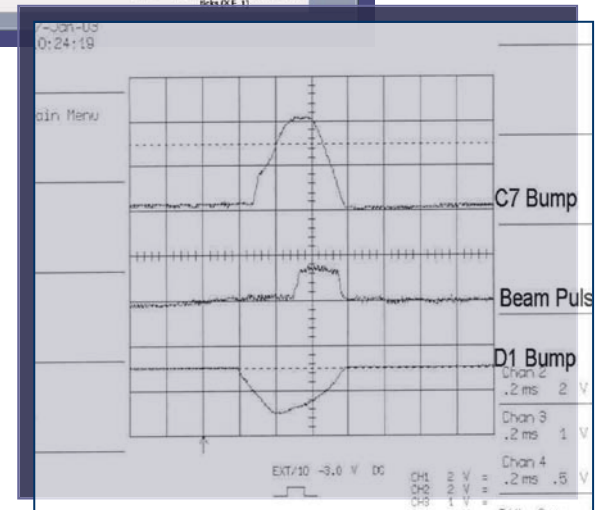
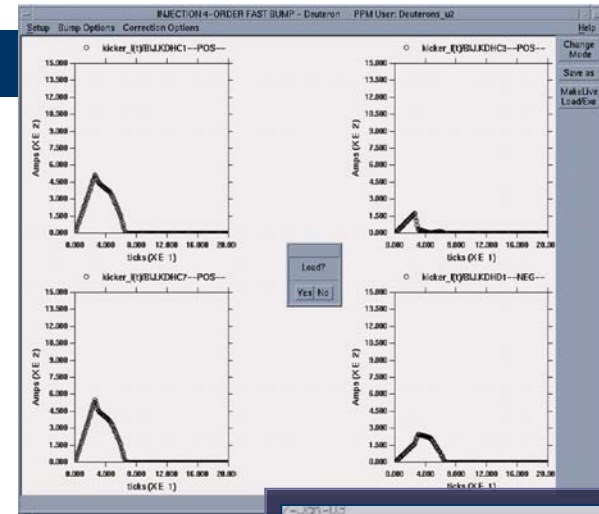
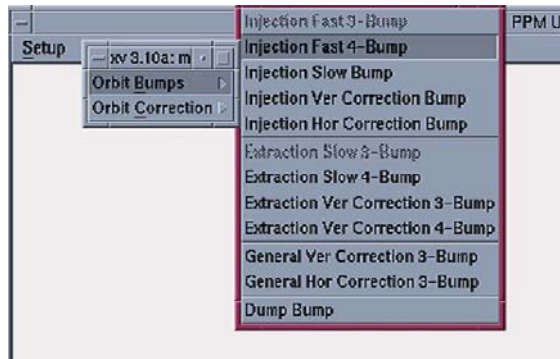
- If there is no beam observed in section 27, call Tandem Operations
- If beam is observed past in section 27, check:
  - Intensities with current transformers
  - Positions and shapes with harps – compare to known good values

# Intermittent or Little Beam in Booster

- Check that the beam is getting to the Booster
  - Check the LTB harps and Transformers.
- Booster input stable?
  - If no, check the source output
  - If the amplitude or width is unstable, the source will need adjustment

# No Circulation in Booster

- Turn the RF off
- Are injection bumps working properly?





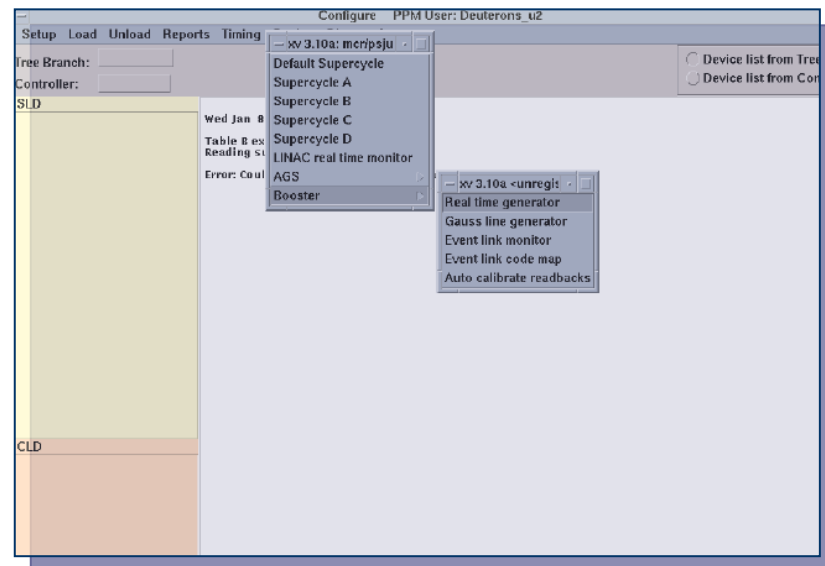
# Charge State

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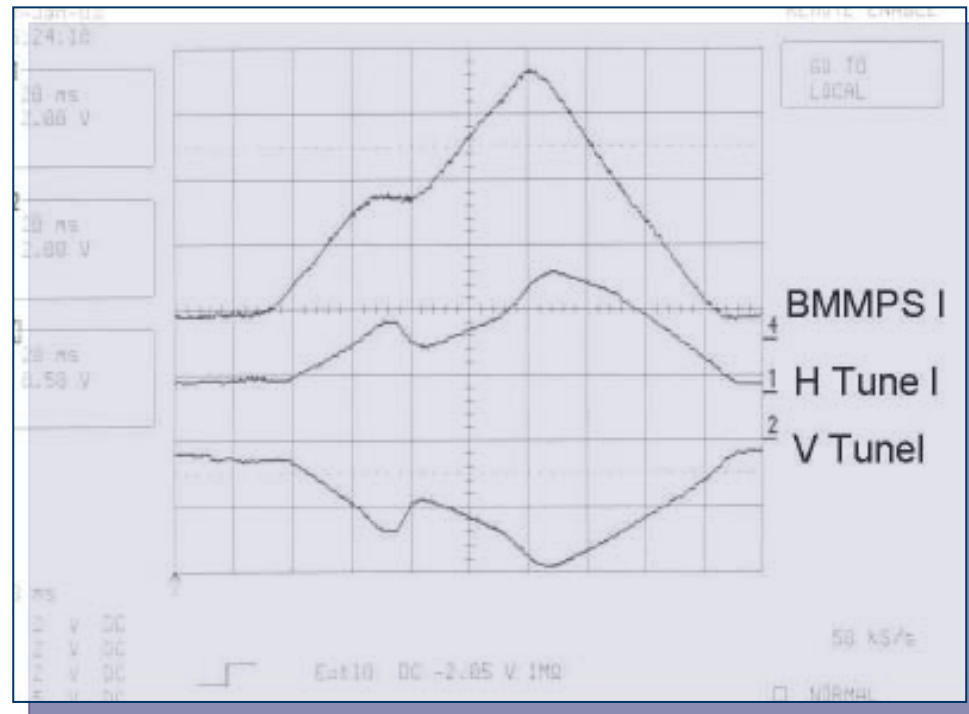
- If adjusting inflector is the only means of producing poorly circulating beam perhaps charge state is incorrect
  - Contact Tandem Controls

# No Injection Transformer Signal

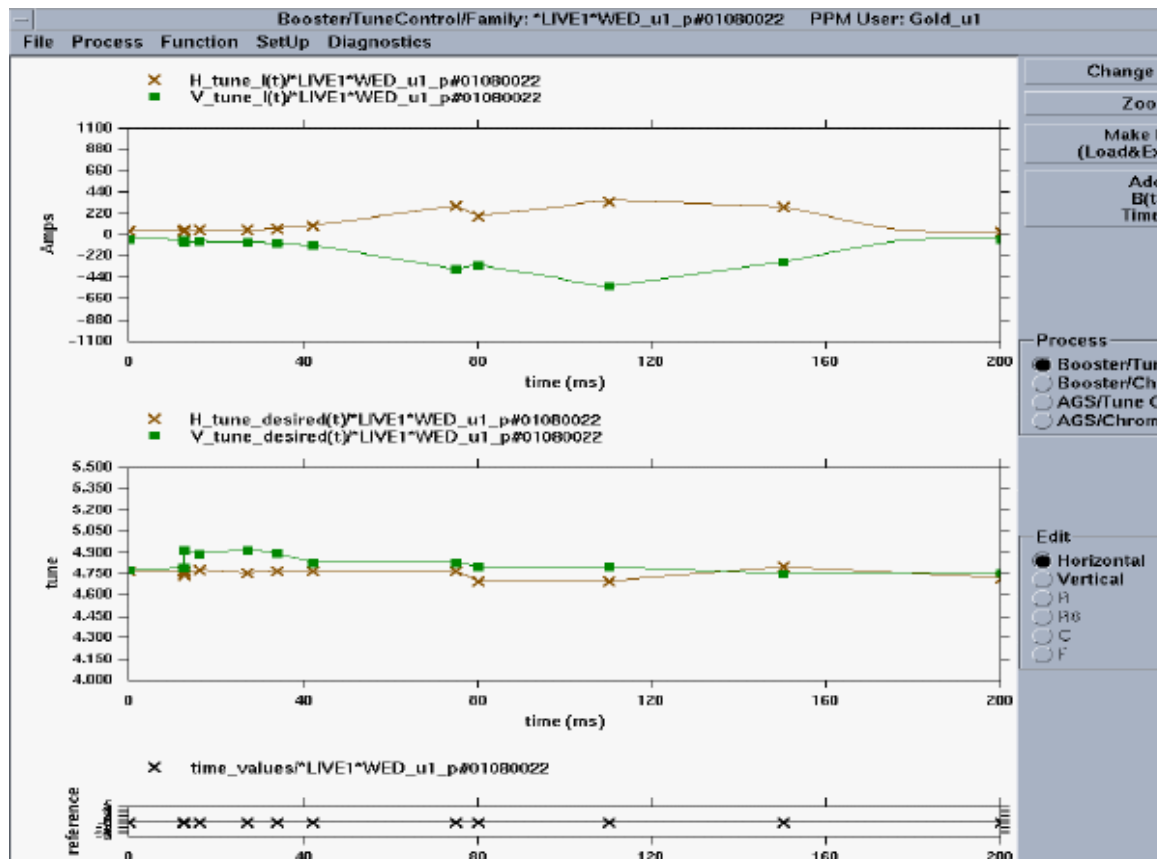
- Check Dwell Field.
  - In Configure:
    - Select '*Timing/Booster/Auto Calibrate Read Backs*'



# Check High-Field Magnets



# Tune Control



# Vertical Tune

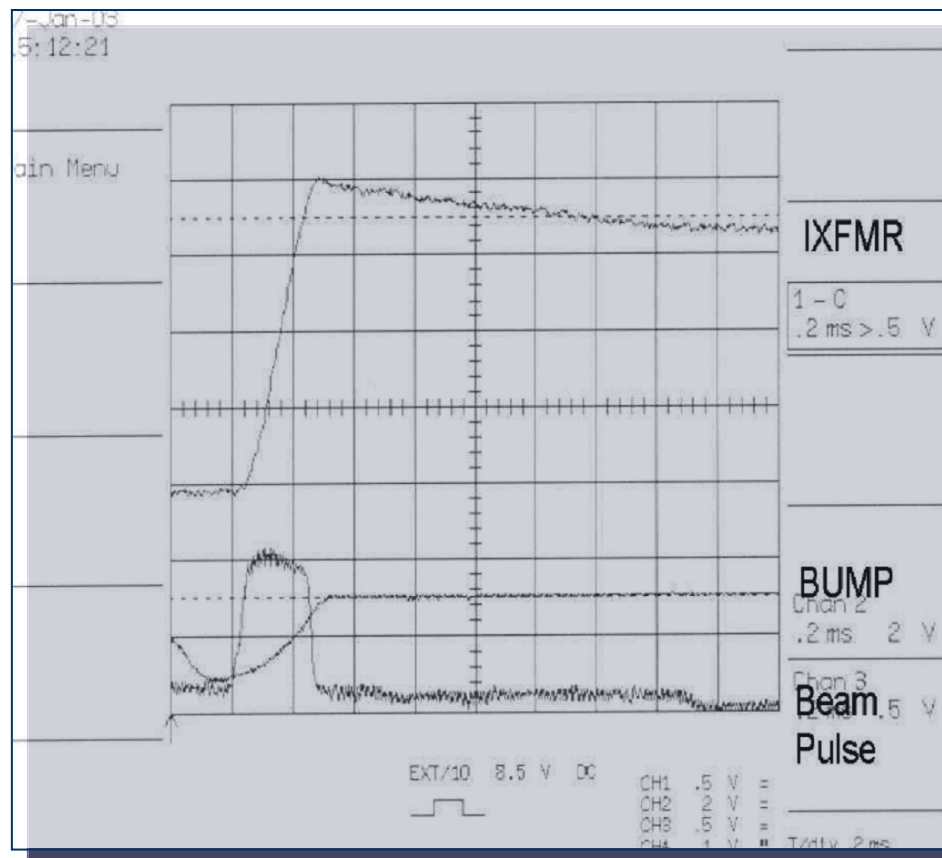
- Often when running high intensity protons, Booster is set up such that the vertical tune is very close to 5, an integer resonance capable of causing rapid beam loss
- Lowering the tune by .05 units will allow beam survival
- The tune can then be optimized after beam is re-established

# Bump Timing

- Injection bumps and beam pulse must be properly aligned to allow injection.
- The following illustrates proper timing for heavy ion operation
- Note that the beam pulse is aligned with the collapsing edge of the bump



# Injection Bump



# Other Possible Interruptions

- Check correctors
- Check dump bump
- Check that extraction equipment is not on during injection
- Is the foil in? (yes for protons, no for ions)

# Conclusions

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- Injection into the Booster in the first stage of acceleration critical to MCR operations
- Problems can usually be found and corrected when a structured approach is used in deciphering symptoms
- Subtleties in injection are learned over time and with experience...

# Troubleshooting Checklist

Symptom	Possible Problem	Method for Finding	Solution
No beam in transport line.	Tripped or maladjusted element.	Check for alarm on ADT. Look in pet.	Turn on or send correct value to element. Ensure beamstops are opened.
No beam in transport line.	No source output	Use TV to look at LINAC source. Contact Tandem personnel to inquire about Tandem source.	Tune source to regain normal output.
No beam in transport line.	Obstruction in line.	Check ADT for Vacuum alarms. Check pet for cups/foils/harps	Correct any vacuum problems and open valves. Put cups/harps/foils to proper positions.
No beam in transport line.	LEBT timing problem.	Look at scope in LCR for beam pulse vs. solenoid pulse timing.	Move timing parameters to get solenoid pulse and beam aligned.

# Troubleshooting (Continued)

Symptom	Possible Problem	Method for Finding	Solution
Beam in Transport, not Booster.	Injection foil in/out	Check pet	Put foil in proper position (in for protons, out for ions).
Beam in Transport, not Booster.	Injection bumps malfunctioning/miss-times	Check ADT. Set up scope to look at bumps and beam pulse.	Re-load functions/repair power supplies and adjust timing as needed.
Beam in Transport, not Booster.	High field magnets not on/Bad function	Check ADT. Look at expected functions (applications) and analog signals (scope).	Repair faults, turn on and load proper functions.
Beam in Transport, not Booster.	Low field supplies wrong/bad function or off.	Check ADT. Look on spreadsheet. Check analog signals.	Repair faults, turn on and load proper functions.